

TECHNICAL FIELD OF THE INVENTION

This invention relates in general to configuration of a product and, more particularly, to a method for facilitating configuration of one of a plurality of different products from a set of components which can be selectively combined in different ways.

[illegible]

BACKGROUND OF THE INVENTION

Systems are frequently developed which involve a plurality of related components that can be selectively combined in different ways to form a plurality of different products. In some situations, the total number of possible combinations of the components is astronomical, but only a subset of these combinations actually represent valid products. Even so, there can still be a relatively large number of the combinations that represent valid products.

In some situations, the manufacturer selects a small handful of the valid combinations to serve as pre-configured products that will actually be manufactured and marketed. On the other hand, there are applications in which it is desirable to give prospective purchasers the capability to obtain any of the various component combinations that represent valid products, so that each purchaser receives a product which is custom tailored to meet the needs of that purchaser's particular application. However, where the number of valid component combinations is relatively large, and/or where the product is technically complex, this can present a very difficult problem. In particular, the problem is that it is difficult for the prospective purchaser to configure a product, unless he or she first spends a substantial amount of time becoming intimately familiar with technical details of the various components and with the permissible and impermissible ways of combining them.

In order to address this problem, techniques have previously been developed to facilitate configuration of various products from a set of components. In some cases, these techniques have been incorporated into tools like computer programs, which can present one or more questions to a prospective purchaser, and then use the answers to

automatically configure a product that meets the purchaser's needs.

While these existing techniques and tools have been generally adequate for their intended purposes, they have not been satisfactory in all respects. In this regard, the process of developing such a tool for any new product has traditionally been a tedious and painstaking task. Identification of an appropriate set of questions typically involves a significant amount of intelligent guessing, and trial and error experimentation. The time required to develop such a tool for any new product is substantial, and may span a number of weeks or even a number of months. In some cases, introduction of the product to the marketplace may need to be delayed until the tool is ready. Alternatively, the product may need to be introduced without the support of a suitable tool, which may adversely affect customer reaction during the crucial period of initial product introduction.

A further consideration is that, due to the complexity involved in the development process, the resulting tools may not have the full range of desired capability. For example, some valid combinations of components may be inadvertently overlooked, such that the resulting tool may not be capable of providing a purchaser with certain valid combinations of components, with the result that the purchaser receives a product that is not optimum for his or her particular application.

SUMMARY OF THE INVENTION

From the foregoing, it may be appreciated that a need has arisen for a method for facilitating configuration of products from a plurality of different components, permitting a suitable configuration procedure to be developed more rapidly and more accurately than is the case with known techniques. According to the present invention, a method is provided to address this need, and involves: determining whether each component in the set corresponds to a first component class involving components that are required in each product without variation in quantity and type; determining whether each component in the set corresponds to a second component class involving components that are required in each product but that vary among the products with respect to at least one of quantity and type; determining whether each component in the set corresponds to a third component class involving components that are each present in some but not all of the products, the components corresponding to the second and third classes collectively forming a component group; identifying a criteria set having a plurality of different states which each correspond to a respective one of the products; and associating with each state of the criteria set a definition of a combination of the components from the component group which is present in the corresponding product.

BRIEF DESCRIPTION OF THE DRAWINGS

A better understanding of the present invention will be realized from the detailed description which follows, taken in conjunction with the accompanying drawings, in which:

FIGURE 1 is block diagram of a multiplexer apparatus which can be configured into various different products using techniques according to the present invention;

FIGURE 2 is a block diagram of a system in which the apparatus of FIGURE 1 is used to implement a network element known as a terminal;

FIGURE 3 is a block diagram of a system having a Unidirectional Path Switched Ring (UPSR) configuration, in which the apparatus of FIGURE 1 is a UPSR network element;

FIGURE 4 is a block diagram of a system in which the apparatus of FIGURE 1 is used to implement a network element known as a linear add/drop multiplexer;

FIGURE 5 is a view similar to FIGURE 1, but identifying specific components which are used in each of several different sections thereof;

FIGURE 6 is a diagrammatic elevational front view of the apparatus of FIGURE 1;

FIGURE 7 is a flowchart showing a sequence of steps which embody one form of the present invention;

FIGURE 8 is an example of a flowchart developed according to techniques which embody the present invention, and includes several separate figures that are collectively referred to herein as FIGURE 8;

FIGURE 9 is chart showing an analysis relating to one class of components from the apparatus of FIGURE 1; and

FIGURE 10 is a chart showing a similar analysis relating to a different class of components from the apparatus of FIGURE 1.

DETAILED DESCRIPTION OF THE INVENTION

FIGURE 1 is a diagrammatic view of a multiplexer apparatus 10 for a telecommunications system, to which the techniques of the present invention can be applied. For convenience, the apparatus 10 of FIGURE 1 has been selected as one example of an apparatus to which the present invention can be applied. However, the present invention is not in any way limited to a telecommunications product the telecommunications field, but has application to a wide variety of other products in a wide variety of other fields.

As described in more detail below, the multiplexer apparatus 10 of FIGURE 1 is associated with a set of components, which can be selectively combined in many different ways in order to form many different products. The diagram of FIGURE 1 is a generic representation of the architecture that is generally common to all of these products.

Focusing in more detail on FIGURE 1, the apparatus 10 has transport ports 16 and 17, which are coupled to optical fibers in a telecommunications network, and which carry high-speed telecommunications traffic. The transport ports 16 and 17 are sometimes alternatively referred to as line ports. In the disclosed embodiment, the ports 16 and 17 are configured to carry traffic conforming to the industry standard known as the synchronous optical network (SONET) protocol, and in particular either the Optical Carrier 12 (OC-12) or Optical Carrier 3 (OC-3) SONET protocols. However, it will be recognized that the transport ports 16 and 17 could alternatively be use some other existing or future communication protocol. While it is possible to use the ports 16 and 17 to couple the apparatus 10 to other equipment which is local, the ports 16 and 17 will

sl #17 typically be used to couple the apparatus 10 to other equipment which is at remote locations.

As is common in the industry, high priority SONET traffic is typically sent through optical fibers referred to as working fibers, whereas low priority traffic is sent through optical fibers referred to as protection fibers. The provision and use of protection fibers is known in the telecommunications industry, and therefore is described here only briefly, to the extent needed to facilitate an understanding of the present invention. In this regard, if some or all of the working fibers become unavailable, for example because they are inadvertently cut by construction equipment, the lower priority traffic on some or all protection fibers can be interrupted, and then the high priority traffic from the unavailable working fibers is switched over to the protection fibers that have been made available.

The apparatus 10 further includes a service port 22 that can be coupled to a plurality of optical fibers in a telecommunications network, which are commonly referred to as tributaries. The service port 22 is typically used to couple the apparatus 10 to other local equipment, rather than to equipment at remote locations. Telecommunications traffic flowing through the service port 22 will have a speed which is the same as or slower than the speed of telecommunications traffic flowing through the transport ports 16 and 17. In the disclosed embodiment, a wider range of communication protocols is available for the tributary ports than for the transport ports, including both synchronous and asynchronous interfaces. In particular, available synchronous interfaces for the tributary ports include the SONET OC-12 and OC-3 interfaces discussed above. A further option for a synchronous interface is the SONET protocol known in the industry as

EC-1. For an asynchronous interface, the industry standard known as the DS3 protocol is available.

Internally, the multiplexer apparatus 10 has four sections with respective different functions, including a high-speed transport section 41, a switch section 43, a tributary section 46, and a management section 48. The transport section 41 includes circuitry which provides a plurality of interfaces for each of the transport ports 16 and 17. Similarly, the tributary section 46 includes circuitry which provides a plurality of tributary interfaces for the service port 22.

The switch section 43 has a switching function, and operates to dynamically establish paths that route telecommunications traffic between the various optical fibers coupled to each of the transport port 16, the transport port 17, and the service port 22. In other words, any telecommunications traffic which travels through the multiplex apparatus 10 from one of the ports 16-17 and 22 to another of these ports will flow through the switch section 43. As one example, telecommunications traffic being routed from the port 16 to the port 17 will flow through the switch section 43. This involvement of the switch section 43 with the flow of telecommunications traffic is indicated diagrammatically by the double-headed arrows 51 and 52 in FIGURE 1. Depending on the configuration of the apparatus 10, the switch section 43 can include one or two different types of switching circuitry, which are each known as a switch fabric. One is a switch fabric that conforms to an industry standard known as the Synchronous Transport Signal (STS) protocol, and the other is a switch fabric that conforms to an industry standard known as the Asynchronous Transfer Mode (ATM) protocol.

The management section 48 carries out a control function with respect to each of the transport section 41, switch section 43, and a tributary section 46, as indicated diagrammatically by respective double-headed arrows 56-58.

5 Functions implemented by the management section 48 include: interfaces known in the industry as Operational Support Systems (OSS) interfaces; a craft interface, which is a man/machine interface providing external access; synchronization control; alarm and housekeeping functions; and functionality known in the industry as Section Data
10 Communication Channel (SDCC) support. More detail regarding the internal structure of the apparatus 10 will be presented later.

There are various different ways in which the
15 apparatus 10 of FIGURE 1 can be functionally incorporated into a telecommunications network. Three different approaches are of specific interest for purposes of explaining the present invention. In each approach, the multiplex apparatus 10 implements a different function from
20 the point of view of the overall network. Stated differently, the apparatus 10 acts as one of three different types of network element (NE).

In this regard, FIGURES 2-4 are diagrammatic views which each show a simple example of a respective different telecommunications network configuration representing a
25 respective one of the three approaches of interest. In each of FIGURES 2-4, the multiplexer apparatus 10 of FIGURE 1 is shown operatively coupled to one or two other devices that, for simplicity and clarity in explaining the present invention, are depicted as devices of the same type
30 as the apparatus 10. However, these other devices could alternatively be different from the apparatus 10 of FIGURE 1.

In more detail, FIGURE 2 is a diagrammatic view of a network configuration 71 in which the multiplexer apparatus 10 of FIGURE 1 is operatively coupled by a network to an multiplexer apparatus 72. In this network configuration, the apparatus 10 serves as a network element of a type commonly referred to in the industry as a terminal.

FIGURE 3 is a diagrammatic view of a network configuration 81 in which the multiplexer apparatus 10 of FIGURE 1 is operatively coupled by the network to a multiplexer apparatus 82 and a multiplexer apparatus 83. This network configuration is known in the industry as a Unidirectional Path Switched Ring (UPSR), and thus the apparatus 10 serves as a UPSR network element.

FIGURE 4 is a diagrammatic view of a further network configuration 91 in which the multiplexer apparatus 10 of FIGURE 1 is operatively coupled by the network to a multiplexer apparatus 92 and a multiplexer apparatus 93. In this network configuration, the apparatus 10 serves as a network element of a type commonly referred to in the industry as a Linear Add/Drop Multiplexer (Linear ADM).

FIGURE 5 is a diagrammatic view of the multiplexer apparatus 10, which is similar to the view of FIGURE 1 except that it identifies certain specific components that can be used to implement each of the four sections 41, 43, 46 and 48 of the apparatus 10. These specific components are circuit cards. Each will be discussed in more detail later, but FIGURE 5 provides an initial introduction to which of these components relate to which of the four different sections of the multiplexer apparatus 10. Some of these circuit card components will be present in every possible configuration of the apparatus 10, whereas others may or may not be present, depending on the particular configuration. This is also discussed in more detail later. For completeness, FIGURE 5 identifies every circuit

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circuit card component DCA6 that provides what is known in the industry as Data Communications Channel (DCC) capability, and a circuit card component HSA6 that provides switching control when protection is implemented in the apparatus 10. The management section 48 also includes a circuit card component TCA6, which provides timing control for the apparatus 10. If the switch section 43 has ATM switching capability, in particular through use of the component AFA6 as discussed above, then a circuit card component APA6 is provided in the management section 48, and has an ATM processor which provides control that facilitates the ATM switching function.

As mentioned above, the components discussed in association with FIGURE 5 are each a circuit card. While FIGURE 5 highlights each component which is a circuit card, the multiplexer apparatus 10 also includes other components, such as mechanical parts, which will now be discussed in association with FIGURE 6. More specifically, FIGURE 6 is a diagrammatic elevational front view of the multiplexer apparatus 10, showing more structural detail than FIGURE 1.

As shown in FIGURE 6, the multiplexer apparatus 10 includes a shelf assembly 101, which is shown in solid lines in FIGURE 6, and which serves as a mounting platform for other components. In this regard, four cooling fan units 106-109, which have a component name of FAN2, are removably installed in respective slots within the shelf assembly 101. The fans 106-109 facilitate a flow of cooling air through the shelf assembly 101. An air filter 112 is removably installed in a further opening or slot within the shelf assembly 101, and serves to filter the air that is forced to flow through the shelf assembly 101 by the fans 106-109. A heat shield 113 is also installed in the shelf assembly 101, to provide a degree of heat

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slots 131-159 can removably receive a circuit card, in a manner described in more detail later. Some slots must always contain a particular type of circuit card, in every possible configuration of the apparatus 10. Other slots
5 can removably receive circuit cards of different types, depending on the configuration, and in some configurations may contain no card at all. Depending on which circuit cards are present, and in which slots, the multiplexer apparatus 10 can be configured in a variety of different
10 ways, each of which is treated herein as a respective different product.

In FIGURE 6, the five full-height slots 131-135 at the far left end of shelf assembly 101, and the two-half height slots 142-143 at the far right end of the shelf assembly
15 101, collectively correspond to the management section 48 of FIGURES 1 and 5. The remaining six full-height slots 136-141 correspond to the switch section 43 of FIGURES 1 and 5. The two half-height slots 152 and 159 may correspond to either the transport section 41 or the
20 tributary section 52, depending on the particular configuration of circuit cards which is installed. With this mind, the twelve half-height slots 146-151 and 153-158, and in some cases the half-height slots 152 and 159, correspond to the tributary section 46 of FIGURES 1 and 5.
25 The two half-height slots 144 and 145, and in some cases the half-height slots 152 and 159, correspond to the transport section 41 of FIGURES 1 and 5. The various types of circuit cards which can be removably inserted into the slots 131-159 have already been briefly discussed above,
30 and will be discussed in more detail later.

As mentioned earlier, the multiplexer apparatus 10 can be configured in a wide variety of different ways, in part by inserting a selected one of a wide variety of different combinations of circuit cards into the slots 131-159.

Consequently, from the point of view of a prospective purchaser, it could be a rather complex and confusing task to decide which circuit cards and other components should be separately purchased for later assembly into a physical product that will accurately and reliably perform a desired function. An attempt to manually configure a valid product at this level requires substantial technical knowledge regarding the multiplexer apparatus 10, including various considerations such as mechanical and electrical limitations and incompatibilities. The present invention was developed to provide an efficient technique for developing, for a set of components, a methodology that facilitates simple and accurate configuration of any valid product from the myriad of possible combinations of available components. This technique according to the invention will now be explained in the context of the multiplexer apparatus 10 that has been described above in association with FIGURES 1-6.

FIGURE 7 is a high-level flowchart showing a sequence of steps representing one approach to implementation of the technique of the present invention. Each of the steps of FIGURE 7 will first be briefly described at a general level. Then, each step will be described in more detail, in the specific context of the exemplary multiplexer apparatus 10 of FIGURES 1-6.

In FIGURE 7, an inventory list is prepared at 191. This list identifies every single component which is available for separate purchase by a customer and could be a part of any valid configuration of the apparatus which is of interest. In a given product, a given component might be used once, twice or more, or not at all. Next, at 192, a component information package is prepared. This package includes detailed information regarding each of the components in the inventory list, as discussed later.

Then, at 193, each of the components in the inventory list is categorized with respect to whether it corresponds to each of several different classes. A given component can correspond to more than one class. TABLE 1 sets forth three classes that are used in the disclosed embodiment of the invention, and that are referred to herein as Classes 1-3. The references in TABLE 1 to products are references to the set of valid products that can be assembled from the components set forth in the inventory list prepared in block 191 of FIGURE 7. In addition to the three primary classes of components set forth in TABLE 1, the disclosed embodiment of the invention recognizes a fourth class directed to ancillary components, which are components that are related to valid products, but are not a direct physical part of those products.

Next, at block 196 of FIGURE 7, one or more criteria sets are developed. In the disclosed embodiment, and as discussed later, a first criteria set is developed which provides a mapping between each valid product and a corresponding valid combination of components from Class 2. A second criteria set is developed to provide a similar mapping between each product and a corresponding valid combination of components from Class 3. The criteria in the second set may overlap with some of the criteria in the first set. A third criteria set is developed to provide a mapping between each product and a corresponding valid combination of components from the ancillary component class, and the criteria in the third set may overlap with criteria from either or both of the first and second criteria sets. In general, the criteria will relate to information that must be obtained from a prospective purchaser in order to know how to configure a product to meet the particular needs of that purchaser, such as product characteristics that must be specified by the

purchaser. For example, in the case of the apparatus 10 of FIGURE 1, a purchaser would need to specify the speed for the transport ports 16 and 17 (as either OC-12 or OC-3).

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TABLE 1 - COMPONENT CLASSES

Class	Description
1	Components that are required in each product without variation in quantity or type.
2	Components that are required in each product but that vary among the products with respect to quantity and/or type.
3	Components that are present in some but not all products, and that may vary with respect to quantity and/or type.

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Then, at block 197 in FIGURE 7, a flowchart is prepared. The flowchart graphically represents both the criteria in the criteria sets, and also the valid combinations of components for each class. An example of such a flowchart is illustrated and described later.

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Each of the steps set forth in the flowchart of FIGURE 7 will become clearer when explained in the context of a specific example, such as the apparatus 10 discussed above in association with FIGURES 1-6. As discussed above, the first step in the flowchart of FIGURE 7 is block 191, which involves preparation of an inventory list setting forth every component which might possibly be used in assembling any of the many products that are valid versions of the multiplexer apparatus 10 of FIGURE 1. TABLE 2 is a component inventory list identifying each of seventeen components that are available for use in assembling the multiplexer apparatus 10 of FIGURE 1. The left column of TABLE 2 contains arbitrary and sequential item numbers

which each identify a respective one of the seventeen components listed in TABLE 2, in order to help clearly identify particular components in the following discussion of TABLE 2. The next column gives a part name for each component type, and in this regard it will be noted that item 17 in TABLE 2 is a single component (IFA6-xxx1) which has twelve different types with respective different part numbers. This is because these twelve types of circuit card are all extremely similar, in that they each implement optical channel interfaces of either the OC-12 or OC-3 type. Some differ from each other only as to what type of industry-standard connector they use (SC, FC or ST). The remaining column(s) provide a brief description for each type of component listed in TABLE 2.

A comment is appropriate at this point regarding the information set forth in TABLE 2. Item 7 in TABLE 2 includes both the extended shelf 121 (FIGURE 6) and the associated cable 122. Item 8 in TABLE 2 is a spare cable which is identical to the cable shown at 122 in FIGURE 6. Items 7 and 8 in TABLE 2 each refer to the cable because a purchaser has the option of purchasing item 7, or both item 7 and item 8. If a purchaser buys item 7, the purchaser gets both the extended shelf 121 and the cable 122. In contrast, if the purchaser buys item 7 and also item 8, the purchaser gets the extended shelf 121 and two of the cables 122, one of which serves as a spare cable.

TABLE 2 - COMPONENT INVENTORY LIST

	Name	Description
1	Shelf	Shelf assembly
2	FAN2	Fan unit
3	Air Filter	Replaceable air filter
4	Heat Shield	Heat shield

5	CBP	Circuit breaker panel		
6	CB Kit	30 ampere circuit breakers		
7	DS3 ExtShelf	DS3 extension shelf, with cable		
8	DS3 CAB1	Spare cable for DS3 extension shelf		
9	MPA6-CPU1	Microprocessor unit		
10	DCA6-MEM1	Data communication channel (DCC) unit		
11	HSA6-AHB1	High speed switch unit		
12	TCA6-ST31	Timing control unit		
13	SFA6-SF11	STS switch fabric		
14	APA6-AP21	ATM processor unit		
15	AFA6-AF21	ATM switch fabric		
16	IFA6-D3U1	DS3/EC-1 interface unit		
17	IFA6-C3B1	SC connector	short reach	OC-3 interface
	IFA6-F3B1	FC connector		
	IFA6-T3B1	ST connector		
	IFA6-C3E1	SC connector	long/ intermediate reach	
	IFA6-F3E1	FC connector		
	IFA6-T3E1	ST connector		
	IFA6-C2B1	SC connector	short reach	OC-12 interface
	IFA6-F2B1	FC connector		
	IFA6-T2B1	ST connector		
	IFA6-C2D1	SC connector	long reach	
	IFA6-F2D1	FC connector		
	IFA6-T2D1	ST connector		

The next step in FIGURE 7 is block 192, and involves preparation of a component information package. As discussed above, this component information package includes detailed information for each component which is in the inventory list. Among other things, the information

for each component includes an identification of each of the types of that component, and also includes configuration rules for that component. Configuration rules identify the conditions under which a particular type and quantity of cards are used, and the designated slot numbers for each of these cards. The component information package for the multiplexer apparatus 10 of FIGURE 1 is set forth in TABLE 3. It will be noted that TABLE 3 includes seventeen entries, each of which corresponds to a respective one of the seventeen components identified in the inventory list of TABLE 2. TABLE 3 is believed to be self-explanatory, and thus a detailed discussion of TABLE 3 here would be redundant to TABLE 3 itself.

TABLE 3 - COMPONENT INFORMATION PACKAGE

MPA6-CPU1 (Microprocessor Unit)

Network element shelf controller unit, class A.
Functions as the main processing platform for the system, providing the software platform to handle various command syntax to and from the network element. It also supports all the configuration, fault, state, and alarm management software.

Features:

- Network element central processing plug-in unit
- Craft port and external modem interface port
- Alarm management and processing (monitoring and provisioning)
- Non-volatile random access memory storage for software and database parameters
- Software download
- Remote memory backup and restore
- 7-layer open systems interconnect and transaction language 1

Usage:

One MPA6-CPU1 is required per shelf.

Slot Assignments:

Slot #6X001

Configuration Rules:

One MPA6-CPU is required in slot #6X001.

DCA6-MEM1 (DCC Unit)

DCC processor unit, class A. Handles Section DCC (SDCC) communications, and outputs office alarms from the shelf to external devices.

Features:

- Support for 16 SDCCs
- Alarm light emitting diodes (LEDs) on plug-in unit's front panel
- Visual and audible alarm relay outputs
- 16 housekeeping inputs
- Non-volatile random access memory (secondary and standby) of provisioning data and program files
- Local area network (LAN) interface

Usage:

One DCA6-MEM1 is required per shelf.

Slot Assignments:

Slot #6X002

Configuration Rules:

One DCA6-MEM1 is required in slot #6X002.

HSA6-AHB1 (High-Speed Switch Unit)

High-speed protection switching unit, class A.
Controls the equipment and facility (line) protection switching. One HSA6-AHB1 plug-in unit is used in each shelf and serves as the central controller for communications between plug-in units.

Features:

- Switching control of the equipment interface plug-in units
- 1+1 non-revertive automatic protection switching (APS) of the OC-3 and OC-12 line and may be provisioned for unidirectional or bidirectional switching
- Processing of SONET overhead bytes
- Detection of installed plug-in units
- Provisioning information distribution to plug-in units
- Alarm, inventory, and performance monitoring data collection from other plug-in units

Usage:

One HSA6-AHB1 is required per shelf.

Slot Assignments:

Slot #6X003

Configuration Rules:

One HSA6-AHB1 is required in slot #6X003.

APA6-AP21 (ATM Processor Unit)

This is the central processor responsible for ATM data switching, and works in conjunction with the ATM-SF Interface Unit in provisioning permanent virtual circuits (PVC), and performing operations,

administration, and maintenance (OAM) functions on all incoming and outgoing cells.

Features:

- 32 Mbytes DRAM main memory
- 2 Mbytes FLASH memory
- Software downloadable
- CAC for virtual path and virtual circuit links
- ATM cell header processing and cell switching scheduler
- ATM database management
- 1:1 equipment protection
- 2.5G of switch fabric control

Usage:

Two APA6-AP21 are used when ATM switch fabric control and signaling is required.

Slot Assignments:

Slots #6X004 and #6X005

Configuration Rules:

If ATM switch fabric control and signaling is required, then two APA6-AP21 are required in slots #6X004 and #6X005.

TCA6-ST31 (Timing Control Unit)

Stratum 3 synchronization unit. Provides a frequency reference to the system from a variety of timing

sources. The timing sources can be external or internal.

Features:

- Stratum 3 oscillator
- Synchronization status messaging support
- Provisionable timing source priority list
- Selection of highest quality timing source available from various external sources or from internal oscillator
- 1:1 equipment protection

Usage:

Two TCA6-ST31 are required per shelf.

Slot Assignments:

Slots #6X012 and #6X013

Configuration Rules:

Two TCA6-ST31 are required in slots #6X012 and #6X013.

AFA6-AF21 (ATM-SF Interface Unit)

2.5 Gbps ATM switch fabric. Receives ATM cells on an input port and switches them to an output port. Works in conjunction with the ATM Processor Unit to switch and route ATM cells. Each ATM-SF unit supports a 48 STS bandwidth, broken down into 4 STS-12 signals.

Features:

- Virtual path and virtual channel cell switching
- Nonblocking fabric to minimize cell loss rate
- Support for 16000 virtual path and virtual channel links
- Support for 8000 virtual path and virtual channel

cross-connects

- Usage parameter control and congestion marking (explicit forward congestion indicator)
- Support for virtual path tunneling (virtual ATM interface) and virtual path protection
- SONET path termination, origination, and alarming
- F4/F5 OAM (operations, administration and maintenance) functions (AIS, RDI, and loopback)
- Throughput of 2.5G
- 1:1 equipment protection
- Support of five different traffic classes
 - Constant bit rate (CBR)
 - Real-time variable bit rate (rt-VBR)
 - Non-real time variable bit rate (nrt-VBR)
 - Available bit rate (ABR)
 - Unspecified bit rate (UBR)

Usage:

Two AFA6-AF21 are used when ATM interface capability is required.

Slot Assignments:

Slots #6X006 and #6X008

Configuration Rules:

If ATM interfaces capability is required, then two AFA6-AF21 are required in slots #6X006 and #6X008.

SFA6-SF11 (STS-SF Interface Unit)

6G STS switch fabric 120x120 throughput, 48 STS-1 each feed the virtual tributary (VT) and ATM sub-fabric, class A. Provides STS-1 cross-connect functionality (time slot interchange), and STS-1 path monitoring.

Features:

- STS-1, STS-3c, and STS-12c cross-connects
- Full Time Slot Interchange (TSI) capability
- STS provisionable redline, path switch default, and revertive operation
- 120 x 120 STS-1 switch fabric
- 48 STS-1 feeds to virtual tributary (VT) and ATM sub-fabric

Usage:

Two SFA6-SF11 are required per shelf.

Slot Assignments:

Slots #6X010 and #6X011

Configuration Rules:

Two SFA6-SF11 are required in slots #6X010 and #6X011.

IFA6-xxx1 (OC-3 or OC-12 Interface Unit)

IFA6-x3B1 - OC-3 interface; short reach; multi-mode and single-mode fiber; SC (C3B1), FC (F3B1), or ST (T3B1) type fiber-optic connectors.

IFA6-x3E1 - OC-3 interface; intermediate/long reach; SC (C3E1), FC (F3E1), or ST (T3E1) type fiber optic connectors.

IFA6-x2B1 - OC-12 interface, short reach; multi-mode and single-mode fiber; SC (C2B1), FC (F2B1), or ST (T2B1) fiber optic connectors.

IFA6-x2D1 - OC-12 interface, long reach; temperature hardened; SC (C2D1), FC (F2D1), or ST

(T2D1) type fiber optic connectors.

Each IFA6-x3x1 unit provides a universal OC-3 interface for line or tributary, and multiplexes/de-multiplexes three STS-1. Each IFA6-x2x1 unit provides a universal OC-12 interface for line or tributary, and multiplexes/de-multiplexes twelve STS-1.

Features:

- All IFA6-x3x1:
 - OC-3 optical interface
 - STS-1 and STS-3c payload support
 - Provisionable SONET and synchronous digital hierarchy (SDH) STM-1 payload support
 - Synchronization status messaging support
 - ATM cell mapping
 - Universal interface for line or tributary applications in any IFA6 slot
 - Terminal, linear ADM, and UPSR application support
 - 1310nm, single-mode or multi-mode fiber support
 - Available with FC (F3x1), ST (T3x1), or SC (C3x1) type fiber optic connectors/adaptors
- Additional for IFA6-x3B1:
 - OC-3 short reach interface
 - Support of multi- and single-mode fiber
 - Standard temperature operation

- Additional for IFA6-x3E1:
 - Software provisionable for OC-3 intermediate and long-reach applications
 - Support of single-mode fiber
 - Extended temperature operation
- All IFA6-x2x1 units:
 - OC-12 optical interface
 - STS-1, STS-3c, and STS-12c payload support
 - Provisionable SONET and synchronous digital hierarchy (SDH) STM-4 support
 - Synchronized status messaging support
 - ATM mapping support
 - Universal interface for line or tributary in all IFA6 slots
 - Support of Terminal, linear ADM, and UPSR applications
 - 1310nm, single-mode or multi-mode fiber support
 - Available with FC (F2x1), ST (T2x1), and SC (C2x1) fiber optic connectors/adaptors
- Additional for IFA6-x2B1:
 - OC-12 short reach interface
 - Support of multi- and single-mode fiber
 - Standard temperature operation
- Additional for IFA6-x2D1:
 - OC-12 long reach interface
 - Support of single-mode fiber

- Extended temperature operation

Usage:

For line interfaces, one IFA6-x3x1 is used per OC-3 line (working or protect). For tributaries, two IFA6-x3x1 are used per protected OC-3 interface to a maximum of seven protected OC-3 tributaries. One IFA6-x3x1 is used per unprotected OC-3 tributary to a maximum of 14 unprotected OC-3 tributaries.

For line interfaces, one IFA6-x2x1 is used per OC-12 line (working or protect). For tributaries, two IFA6-x2x1 are used per protected OC-12 interface to a maximum of seven protected OC-12 tributaries. One IFA6-x2x1 is used per unprotected OC-12 tributary to a maximum of 14 unprotected OC-12 tributaries.

Slot Assignments:

OC-3: Slots #6X101, #6X102, #6X109, and #6X116 for transport; slots #6X103-#6X116 for tributaries.

OC-12: Slots #6X101, #6X102, #6X109, and #6X116 for transport; slots #6X103-#6X115 for tributary.

Configuration Rules:

For OC-3 line interfaces,

- If network element Type is Terminal,
 - If short reach OC-3 lines are required,
 - If protected OC-3 line interface is required, then two IFA6-x3B1 are required in slots #6X101 & #6X102.

- If unprotected OC-3 line interface is required, then one IFA6-x3B1 is required for each OC-3 line in slots #6X101.
- If intermediate or long reach OC-3 lines are required,
 - If protected OC-3 line interface is required, then two IFA6-x3E1 are required for each OC-3 line in slots #6X101 and #6X102.
 - If unprotected OC-3 line interface is required, then one IFA6-x3E1 is required in slots #6X101.
- If network element Type is UPSR,
 - If short reach OC-3 lines are required, then two IFA6-x3B1 are required in slots #6X101 & #6X102.
 - If intermediate or long reach OC-3 lines are required, then two IFA6-x3E1 are required in slots #6X101 and #6X102.
- If network element Type is Linear ADM,
 - If short reach OC-3 line interface is required,
 - If protected OC-3 line interfaces are required, then four IFA6-x3B1 are required in slots #6X101 & #6X102, and #6X109 & #6X116.
 - If unprotected OC-3 line interfaces are required, then two IFA6-x3B1 are required in slots #6X101 and #6X109.
 - If intermediate or long reach OC-3 line interface is required,

- If protected OC-3 line interfaces are required, then four IFA6-x3E1 are required in slots #6X101 & #6X102, and #6X109 & #6X116.
- If protected OC-3 line interfaces are required, ~~then two IFA6-x3E1 are required in slots #6X101 and #6X109.~~

For OC-3 tributaries,

- If network element Type is Terminal or UPSR,
 - If short reach is required,
 - If protected OC-3 tributaries are required, then two IFA6-x3B1 are required for each protected OC-3 tributary in slots #6X103 & #6X104, #6X105 & #6X106, #6X107 & #6X108, #6X110 & #6X111, #6X112 & #6X113, #6X114 & #6X115, and #6X109 & #6X116, as needed.
 - If unprotected OC-3 tributaries are required, then one IFA6-x3B1 is required for each unprotected OC-3 tributary in slots #6X103-#6X116, as needed.
 - If intermediate or long-reach is required,
 - If protected OC-3 tributaries are required, then two IFA6-x3E1 are required for each protected OC-3 tributary in slots #6X103 & #6X104, #6X105 & #6X106, #6X107 & #6X108, #6X110 & #6X111, #6X112 & #6X113, #6X114 & #6X115, and #6X109 & #6X116, as needed.
 - If unprotected OC-3 tributaries are required, then one IFA6-x3E1 is required

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for each unprotected OC-3 tributary in slots #6X103-#6X116, as needed.

- If network element Type is Linear ADM,
 - If short reach is required,
 - If protected OC-3 tributaries are required, then two IFA6-x3B1 are required for each protected OC-3 tributary in slots #6X103 & #6X104, #6X105 & #6X106, #6X107 & #6X108, #6X110 & #6X111, #6X112 & #6X113, and #6X114 & #6X115, as needed.
 - If unprotected OC-3 tributaries are required, then one IFA6-x3B1 is required for each unprotected OC-3 tributary in slots #6X103-#6X108 and #6X110-#6X115, as needed.
 - If intermediate or long-reach is required,
 - If protected OC-3 tributaries are required, then two IFA6-x3E1 are required for each protected OC-3 tributary in slots #6X103 & #6X104, #6X105 & #6X106, #6X107 & #6X108, #6X110 & #6X111, #6X112 & #6X113, and #6X114 & #6X115, as needed.
 - If unprotected OC-3 tributaries are required, then one IFA6-x3E1 is required for each unprotected OC-3 tributary in slots #6X103-#6X108 and #6X110-#6X115, as needed.

For OC-12 line interfaces,

- If network element Type is Terminal,

- If short reach OC-12 lines are required,
 - If protected OC-12 line interface is required, then two IFA6-x2B1 are required in slots #6X101 & #6X102.
 - If unprotected OC-12 line interface is required, then one IFA6-x2B1 is required for each OC-12 line in slots #6X101.
- If intermediate or long reach OC-12 lines are required,
 - If protected OC-12 line interface is required, then two IFA6-x2E1 are required for each OC-12 line in slots #6X101 & #6X102.
 - If unprotected OC-12 line interface is required, then one IFA6-x2E1 is required in slots #6X101.
- If network element Type is UPSR,
 - If short reach OC-12 lines are required, then two IFA6-x2B1 are required in slots #6X101 & #6X102.
 - If intermediate or long reach OC-12 lines are required, then two IFA6-x2E1 are required in slots #6X101 & #6X102.
- If network element Type is Linear ADM,
 - If short reach OC-12 line interface is required,
 - If protected OC-12 line interface is required, then two IFA6-x2B1 are required in slots #6X101 & #6X102, and #6X109 & #6X116.

- If unprotected OC-12 line interface is required, then one IFA6-x2B1 is required in slots #6X101 and #6X109.
- If intermediate or long reach OC-12 line interface is required,
 - If protected OC-12 line interface is required, then two IFA6-x2E1 are required in slots #6X101 & #6X102, and #6X109 & #6X116.
 - If unprotected OC-12 line interface is required, then one IFA6-x2E1 is required in slots #6X101 and #6X109.

For OC-12 tributaries,

- If network element Type is Terminal or UPSR,
 - If short reach is required,
 - If protected OC-12 tributaries are required, then two IFA6-x2B1 are required for each protected OC-12 tributary in slots #6X103 & #6X104, #6X105 & #6X106, #6X107 & #6X108, #6X110 & #6X111, #6X112 & #6X113, #6X114 & #6X115, and #6X109 & #6X116, as needed.
 - If unprotected OC-12 tributaries are required, then one IFA6-x2B1 is required for each unprotected OC-12 tributary in slots #6X103-#6X116, as needed.
 - If intermediate or long-reach is required,
 - If protected OC-12 tributaries are required, then two IFA6-x2E1 are required for each protected OC-12 tributary in slots #6X103 & #6X104,

#6X105 & #6X106, #6X107 & #6X108, #6X110 & #6X111, #6X112 & #6X113, #6X114 & #6X115, and #6X109 & #6X116, as needed.

- If unprotected OC-12 tributaries are required, then one IFA6-x2E1 is required for each unprotected OC-12 tributary in slots #6X103-#6X116, as needed.
- If network element Type is Linear ADM,
 - If short reach is required,
 - If protected OC-12 tributaries are required, then two IFA6-x2B1 are required for each protected OC-12 tributary in slots #6X103 & #6X104, #6X105 & #6X106, #6X107 & #6X108, #6X110 & #6X111, #6X112 & #6X113, and #6X114 & #6X115, as needed.
 - If unprotected OC-12 tributaries are required, then one IFA6-x2B1 is required for each unprotected OC-12 tributary in slots #6X103-#6X108 and #6X110-#6X115, as needed.
 - If intermediate or long-reach is required,
 - If protected OC-12 tributaries are required, then two IFA6-x2E1 are required for each protected OC-12 tributary in slots #6X103 & #6X104, #6X105 & #6X106, #6X107 & #6X108, #6X110 & #6X111, #6X112 & #6X113, and #6X114 & #6X115, as needed.
 - If unprotected OC-12 tributaries are required, then one IFA6-x2E1 is required

for each unprotected OC-3 tributary in slots #6X103-#6X108 and #6X110-#6X115, as needed.

5 **IFA6-D3U1 (DS-3/EC-1 Interface Unit)**

This unit provides three DS3 or EC-1 line terminations.

Features:

- IFA6-D3U1:
 - 1:1 protection or 0:2 equipment protection
 - Ports independently provisionable as DS3 or EC-1 ports
 - Line Build Out (LBO) selection
- DS3 ports:
 - Bit error rate monitoring
 - M13, C-Bit, and clear channel applications
 - DS3 user network interface (UNI) for ATM applications, physical layer convergence protocol (PLCP) and direct mode
 - Terminal and Facility Loopback functions
- EC-1 ports:
 - Synchronization status messaging
 - Section Data Communications Channel (SDCC)
 - ATM cell mapping support

Usage:

Two IFA6-D3U1 are used per 1:1 protected DS3/EC-1 interface to a maximum of twelve units (18 DS3/EC-1) per shelf. One IFA6-D3U1 is used per 1:1 unprotected

DS3/EC-1 interface to a maximum of six units (18 DS3/EC-1) per shelf. Additional 36 DS3/EC-1 interfaces are provided by converting the protection IFA6-D3U1 units to working by adding the DS3 extension shelf.

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Slot Assignments:

Slots #6X103-#6X116

Configuration Rules:

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If network element Type is Terminal or UPSR,

- If DS3/EC-1 tributaries are required,
 - If the number of tributary signals is between one and 18 DS3/EC-1,
 - If 1:1 protection is required, then two IFA6-D3U1 are required per three DS3 or EC-1 in slots #6X103 & #6X104, #6X105 & #6X106, #6X107 & #6X108, #6X110 & #6X111, #6X112 & #6X113, #6X114 & #6X115, and #6X109 & #6X116, as needed.
 - If 1:1 protection is not required, then one IFA6-D3U1 is required per three DS3 or EC-1 in any of slots #6X103 through #6X116, as needed.
- If more than 18 DS3/EC-1 are required, then one IFA6-D3U1 is required per three DS3 or EC-1 in slots #6X103, #6X104, #6X105, #6X106, #6X107, #6X108, #6X110, #6X111, #6X112, #6X113, #6X114, #6X115, and #6X116 as needed.

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If network element Type is Linear ADM,

- If DS3/EC-1 tributaries are required,

- If the number of tributary signals is between one and 18 DS3/EC-1,
 - If 1:1 protection is required, then two IFA6-D3U1 are required per three DS3 or EC-1 in slots #6X103 & #6X104, #6X105 & #6X106, #6X107 & #6X108, #6X110 & #6X111, #6X112 & #6X113, and #6X114 & #6X115, as needed.
 - If 1:1 protection is not required, then one IFA6-D3U1 is required per three DS3 or EC-1 in any of slots #6X103 through #6X108, and #6X110 through #6X115, as needed.
- If more than 18 DS3/EC-1 are required, then one IFA6-D3U1 is required per three DS3 or EC-1 in slots #6X103, #6X104, #6X105, #6X106, #6X107, #6X108, #6X110, #6X111, #6X112, #6X113, #6X114, and #6X115, as needed.

Shelf (Shelf Assembly)

This is a modular shelf which houses the plug-in units, and which has four sections (Transport, Tributary, Switch, and Management).

Features:

- Modular design
- Management section of five slots plus two for timing control
- Switch section of six slots
- Four Transport interface slots (two are optional

tributary slots)

- Twelve Tributary interface slots plus two optional Transport slots
- Integrated fan shelf that houses four FAN2 units

Usage:

One shelf is required per network element.

Slot Assignments:

Not applicable

Configuration Rules:

One shelf is required.

FAN2 (Fan Unit)

This fan unit is designed to maintain temperatures in the shelf within an acceptable range. Each shelf receives 4 removable fans, providing forced cooling for the plug-in units in the shelf.

Features:

- Plug-in unit removal/replacement without traffic interruption
- Problem notification via alarm system

Usage:

Four FAN2 units are required per shelf.

Not applicable (the FAN2 units are installed on top of the shelf).

Four FAN2 units are required at the top of the shelf.

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Features:

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One air filter is required per shelf.

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Not applicable

One air filter is required per shelf.

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The heat shield routes the airflow through the shelf and out the heat shield. The FAN2 units push the air through the heat shield and route it out of the rack.

Features:

- Passive heat baffle

Usage:

5 One heat shield is required per shelf.

Slot Assignments:

Not applicable (The heat shield is installed above the FAN2 units).

Configuration Rules:

One heat shield is required per shelf above the FAN2 units.

Circuit Breaker Panel

Circuit Breaker Panel (CBP)

The circuit breaker panel (CBP) serves as the power distribution, alarm collection, and output center for the system. The CBP provides eight circuit breaker slots (four A and four B) designed to support circuit breakers ranging from 10 to 40 amperes.

Features:

- Eight circuit breaker slots
- Dual -48Vdc A and B inputs and test points
- Screw-type power connector and wire-wrap block for critical, major, and minor alarms, and tripped circuit breaker/fuse and alarm outputs

Usage:

One circuit breaker panel is provided per rack, where needed.

Slot Assignments:

Not applicable

Configuration Rules:

One circuit breaker panel is provided per rack, where needed.

Circuit Breaker Kit

Circuit Breaker Kit (30A circuit breakers)

The CB kit includes the necessary circuit breakers for the specified standard rack configuration.

Features:

- 30A circuit breakers

Usage:

One circuit breaker kit is required per shelf.

Slot Assignments:

Not applicable

Configuration Rules:

One circuit breaker kit is required per shelf.

DS3 Extended Shelf

DS3 EXTSHELF - DS3 extension panel (or shelf), with cable.

The DS3 extended shelf provides an additional 18 DS3 unprotected ports (BNC connectors) per shelf. The

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- Extension of connection for DS3 interface units
- Addition of BNC connectors for additional 18 unprotected DS3 interfaces

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Not applicable

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DS3 Spare Cable

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Usage :

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Not applicable

One DS3 spare cable is provided where specified.



In FIGURE 7, the next step is step 193, where each component is categorized with respect to each of the four component classes discussed above, in particular the three component classes identified in TABLE 1, as well as the ancillary component class. With respect to the multiplexer apparatus 10 of FIGURE 1, and the seventeen components thereof which are identified in the inventory list of TABLE 2, the resulting classification is shown in TABLE 4.

TABLE 4 - CLASSIFICATION OF COMPONENTS

Class	Component
1	Shelf FAN2 Air Filter Heat Shield MPA6-CPU1 DCA6-MEM1 HSA6-AHB1 TCA6-ST31 SFA6-SF11
2	IFA6-xxx1 (transport)
3	APA6-AP21 AFA6-AF21 IFA6-xxx1 (tributary) IFA6-D3U1 (tributary) DS3 ExtShelf
Ancillary	CBP CB Kit DS3 CAB1

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using only item 16 of TABLE 2 and not item 17, the tributary section 46 may conversely be implemented using only item 17 and not item 16. Thus, item 16 is also not required in every product, and is thus listed in Class 3.

5 An ATM interface, which can be implemented using the components identified as items 14 and 15 in TABLE 2, is an option which does not need to be present in every product. Consequently, these two components are classified in Class 3. Finally, the DS3 extension shelf 121 (FIGURE 6),
10 which is item 7 in TABLE 2, is only provided in products where more than eighteen DS3 ports are needed. Therefore, as shown in TABLE 4, the DS3 extension shelf is classified in Class 3.

 As discussed above, the CBP (item 5 in TABLE 2), the
15 CB kit (item 6 in TABLE 2), and the spare cable DS3 CAB1 (item 8 in TABLE 2) are not physically part of the multiplexer apparatus 10 in any configuration. Each may be selectively provided with or omitted from any product version of the multiplexer apparatus 10, depending on the
20 particular situation. For these reasons, they are treated as ancillary components, and are shown as such in TABLE 4.

 In the disclosed embodiment, it is a target or goal that, based on the classification of components set forth in TABLE 4, the total percentage of components
25 corresponding to both of Classes 1 and 2 should be at least 40% of the total number components, where the quantities of these components reflect the maximum number of components that might be present in different products that are respective configurations of the multiplexer apparatus 10.
30 In this regard, TABLES 5 through 10 each address this for a respective different product which is a configuration of the apparatus 10.

 In more detail, TABLES 5-7 represent configurations where the transport interfaces are OC-12 interfaces, and

TABLES 8-10 represent configurations where the transport interfaces are OC-3 interfaces. TABLES 5 and 8 represent a terminal configuration (FIGURE 2), TABLES 6 and 9 represent a UPSR configuration (FIGURE 3) and TABLES 7 and 10 represent a linear ADM configuration (FIGURE 4). The configurations in TABLES 5-10 each use the maximum number of components, including the maximum number of circuit cards that implement tributary interfaces. It will be noted that, in each of the configurations shown in TABLES 5-10, the sum of the percentages for Classes 1 and 2 ranges from 46% to 51% of the total number of components, and thus all six configurations meet the 40% target discussed above. Compliance with the target is advantageous, but not mandatory.

In a situation where the target is not initially met, it may be possible to adjust the initial classification so as to achieve compliance with the 40% target. For example, there may be a component in Class 3 which would not normally be required in each product, but which could be shifted to Class 2 by making it a requirement in each product. In the disclosed embodiment, however, and as evident from TABLES 5-10, no such adjustment is needed.

TABLE 5 - OC-12 TERMINAL

CLASS	CARDS	CARD COUNT	%
1	1 MPA6-CPU1 1 DCA6-MEM1 1 HSA6-AHB1 2 TCA6-ST31 2 SFA6-SF11 1 Shelf 4 FAN2 1 Air Filter 1 Heat Shield	14	40%
2	4 IFA6 (transport)	4	11%
3	12 IFA6 (tributary) 2 AFA6 2 APA6 1 DS3 ExtShelf	17	49%

35 Total Cards

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[illegible]

TABLE 8 - OC-3 TERMINAL

CLASS	CARDS	CARD COUNT	%
1	1 MPA6-CPU1 1 DCA6-MEM1 1 HSA6-AHB1 2 TCA6-ST31 2 SFA6-SF11 1 Shelf 4 FAN2 1 Air Filter 1 Heat Shield	14	40%
2	4 IFA6 (transport)	4	11%
3	12 IFA6 (tributary) 2 AFA6 2 APA6 1 DS3 ExtShelf	17	49%

35 Total Cards

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[illegible]

TABLE 9 - OC-3 UPSR

CLASS	CARDS	CARD COUNT	%
1	1 MPA6-CPU1 1 DCA6-MEM1 1 HSA6-AHB1 2 TCA6-ST31 2 SFA6-SF11 1 Shelf 4 FAN2 1 Air Filter 1 Heat Shield	14	40%
2	2 IFA6 (transport)	2	6%
3	14 IFA6 (tributary) 2 AFA6 2 APA6 1 DS3 ExtShelf	19	54%

35 Total Cards

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[illegible]

TABLE 10 - OC-3 LINEAR ADM

CLASS	CARDS	CARD COUNT	%
1	1 MPA6-CPU1 1 DCA6-MEM1 1 HSA6-AHB1 2 TCA6-ST31 2 SFA6-SF11 1 Shelf 4 FAN2 1 Air Filter 1 Heat Shield	14	40%
2	4 IFA6 (transport)	4	11%
3	12 IFA6 (tributary) 2 AFA6 2 APA6 1 DS3 ExtShelf	17	49%

35 Total Cards

Referring again to FIGURE 7, the next step according to the invention, at block 196, is to develop criteria sets. In the disclosed embodiment, each class of components is handled separately. Beginning with Class 1, and as discussed above, the components of Class 1 are required in each product, and do not vary in quantity or type from product to product. Stated differently, every valid product includes precisely the same combination of components from Class 1. Consequently, no criteria are needed to differentiate between different combinations of components from Class 1. Thus, there is no criteria set associated with Class 1.

Turning to Class 2, and as evident from TABLE 4, the disclosed embodiment has only has one component in Class 2, which is the IFA6-xxx1 component (when used as a transport interface rather than a tributary interface). The

configuration rules in TABLE 3 for this component can be examined with respect to the portions thereof that relate to use of IFA6-xxx1 for transport or line interfaces. This reveals that there are four criteria which determine the quantity and type of this component that will be present in any valid product configuration. The first such criteria is the speed at which the transport interfaces will operate, or in other words whether an OC-12 or OC-3 interface is used.

The second criteria is the type of network element which is to be implemented by the product, and in particular whether the product is to function as a terminal network element (FIGURE 2), a UPSR network element (FIGURE 3), or a linear ADM network element (FIGURE 4). The third criteria is the reach or length of the optical fibers associated with the transport interfaces, and in particular whether these fibers will have a short reach or an intermediate to long reach. The fourth criteria is whether or not each of the transport interfaces will be a protected interface. These four criteria collectively make up the criteria set for Class 2.

Turning now to Class 3, TABLE 4 shows that there are five components in Class 3. Examination of the configuration rules in TABLE 3 for these five components reveals five criteria that identify which combination of Class 3 components should be present in any particular product that is a valid configuration of the multiplexer apparatus 10 of FIGURE 1. One of these criteria overlaps with the criteria discussed above for Class 2. In particular, the first criteria for Class 3 is the network element type, or in other words whether the product is to function as a terminal network element, a UPSR network element, or a linear ADM network element.

The second criteria for Class 3 is whether there is to

be a data interface, or in other words ATM switching capability. The third criteria is the configuration of tributary interfaces, including the number and type of tributary interfaces, where the available types include OC-12, OC-3, and DS3/EC-1. The fourth criteria is whether or not protection capability is to be provided for each of the tributary interfaces. The fifth criteria is the reach associated with the tributary interfaces, and in particular whether each of the tributary interfaces should have a short reach or an intermediate to long reach.

The final criteria set relates to the components in the ancillary class. As evident from TABLE 4, the ancillary class in the disclosed embodiment includes three components. As discussed above, these three components are not an integral physical part of the multiplexer apparatus 10, and each may be optionally included in or excluded from any particular product which is a valid configuration of the multiplexer apparatus. Thus, in the disclosed embodiment, each of the three components has its own simple criteria, reflecting whether or not the purchaser happens to want that particular component in association with a given product.

Referring again to FIGURE 7, block 197 represents the next step, which is to prepare a flowchart that diagrammatically sets forth the various criteria identified in block 196, and that identifies the respective combination of components associated with each valid state or combination of criteria. When the step of block 197 is carried out for the multiplexer apparatus 10 shown in FIGURE 1, the result is the flowchart shown in FIGURE 8. FIGURE 8 is actually composed of several related figures which each show a portion of the overall flowchart, but for convenience and clarity they are all referred to collectively herein as FIGURE 8.

To further facilitate convenience and clarity, the flowchart of FIGURE 8 includes seven nodes 201-207 at various locations, which do not represent functional capability, but instead are provided solely to facilitate an explanation of the flowchart. In particular, the portion of the flowchart between nodes 201 and 202 represents the portion that determines the combination of Class 1 modules which is to be included in the product. From node 202, flow will proceed until it reaches either the node 203 or the node 204, and the portion of the flowchart between node 202 and nodes 203 and 204 effects identification of the combination of Class 2 components which is to be included in the product that is being configured. From node 203 or node 204, flow can continue along one of various paths until it reaches either the node 205 or the node 206. The portion of the flowchart between nodes 203-204 and nodes 205-206 effects identification of the combination of Class 3 components which is to be included in the product that is being configured. From node 205 or node 206, flow will proceed until it reaches node 207, which is at the end of the flowchart. The portion of the flowchart between nodes 205-206 and node 207 effects identification of the combination of components from the ancillary class which will be included in the product that is being configured.

Turning now in more detail to the flowchart, and as mentioned above, the portion of the flowchart between nodes 201 and 202 identifies the combination of Class 1 components which is to be included in any particular product. By definition, as set forth in TABLE 1, this combination is exactly the same for every product which is a valid configuration of the multiplexer apparatus 10 of FIGURE 1. Consequently, this portion of the flowchart includes a single block 212, which sets forth the precise

combination of components from Class 1 that are to be included in every product.

Turning to the components from Class 2, and as mentioned above, the portion of the flowchart between node 202 and nodes 203-204 effects identification of the combination of Class 2 components which will be included in the product that is being configured. In this regard, one of the criteria discussed above for Class 2 is the network element (NE) type for the product, and this is determined at block 214. Another Class 2 criteria discussed above is the speed of the transport interfaces, or in other words whether they are OC-12 or OC-3 interfaces. This is determined at one of three blocks 216-218. A further Class 2 criteria discussed above is whether or not protection is to be provided for the transport interfaces. This is determined at one of four blocks 221-224. The last criteria discussed above for Class 2 is whether the reach or length of the optical fibers for the transport interfaces is to be a short reach or an intermediate to long reach. This is determined at one of ten blocks 226-235.

Depending on the decisions made as the configuration flow passes successively through several of the blocks 214, 216-218, 221-224 and 226-235, the flow will end up at one of twenty blocks 241-260, which each set forth a respective combination of Class 2 components that is to be installed in the product being configured, in order to meet the criteria specified by the purchaser. From each of the twenty blocks 241-260, the configuration flow proceeds to either node 203 or node 204.

Focusing now on the portion of the flowchart which appears between nodes 203-204 and nodes 205-206, this portion determines the particular combination of Class 3 components which will be included in the product. As

discussed above, one criteria for Class 3 is shared with Class 2. This criteria is the network element type for the resulting product. This criteria has already been taken into account at block 214. The decision made at block 214 determines whether the configuration flow eventually arrives at node 203 or node 204. In particular, if the configuration flow arrives at node 203, it is because a determination was made at block 214 that the network element type is either a terminal or UPSR. Alternatively, if the configuration flow arrives at block 204, it is because a determination was made at block 214 that the network element type is a linear ADM. Thus, although this particular criteria is not expressly referred to after blocks 203 and 204, it is being taken account for purposes of Class 3 components.

Another criteria discussed above for Class 3 is whether the product is to include an ATM interface. This is determined at one of two blocks 271 and 272 in FIGURE 8. If ATM interface capability is to be provided, then the configuration flow proceeds to one of two blocks 273 and 274, which each specify the combination of Class 3 components that will be included in the product to provide ATM interface capability. On the other hand, if it is determined at block 271 or block 272 that ATM interface capability is not required, then the configuration flow skips the associated block 273 or 274. In either case, the configuration flow ultimately proceeds to one of blocks 277 or 278.

Another criteria discussed above with respect to Class 3 involves the configuration of tributary interfaces, and in particular the type and quantity of tributary interfaces. In FIGURE 8, this is evaluated at blocks 277 and 278, and then the configuration flow branches in dependence on whether the specified type of tributary

interface is an OC-12 interface, an OC-3 interface, or an EC-1/DS3 interface.

Still another criteria discussed above with respect to Class 3 is whether protection is to be provided for tributary interfaces. This is evaluated next, in one of six blocks 281-286. The remaining criteria discussed above with respect to Class 3 is the length or reach of the optical fibers associated with the tributary interfaces, and in particular whether they have a short reach or an intermediate to long reach. Where this criteria is relevant, it is evaluated at one of eight blocks 291-298. Alternatively, where appropriate, blocks 302 and 303 revisit an issue that was addressed in blocks 277 and 278, namely the number of DS3 tributary interfaces, and in particular whether more than eighteen DS3 interfaces are to be provided in the product.

Based on various decisions made in blocks 214, 277-278, 281-286, 291-298, and 302-303, the configuration flow ultimately arrives at one of twenty-two blocks 311-332, which each set forth a respective combination of Class 3 components. This is in addition to the Class 3 components, if any, which were added in blocks 273-274 in order to provide ATM interface capability. From each of the blocks 311-332, the configuration flow ultimately proceeds to one of the two nodes 205 and 206.

As discussed above, the portion of the flowchart between nodes 205-206 and node 207 determines the extent to which ancillary components will be provided with the product. In more detail, the configuration flow only arrives at node 206 if the DS3 extended shelf 121 is being included in the product in order to provide extra DS3 interfaces. As discussed above, a corresponding cable 122 is automatically provided with the shelf 121, but the purchaser is given the option of ordering an identical

additional cable, which serves as a spare. Consequently, in the flowchart of FIGURE 8, a determination is made at block 337 regarding whether the customer wants a spare cable 122 with the product. If so, then the spare cable is included with the product, as indicated at block 338. Otherwise, block 338 is skipped.

Whether or not the configuration flow passes through block 338, it ultimately reaches block 343, where a CB Kit, or in other words a set of circuit breakers, is unconditionally included with the product. In the disclosed embodiment, a decision was made that circuit breakers would be shipped with every product, and this is reflected in the associated configuration rules in TABLE 3. If the product is used with an existing circuit breaker panel, the circuit breakers can be used in that panel. Alternatively, if the customer elects to purchase the Circuit Breaker Panel (CBP) 116 with the product, the circuit breakers from the CB Kit 117 can be used in the CBP 116.

The configuration flow then proceeds to block 347, where a determination is made regarding whether or not the customer wants the CBP 116 with the product. If so, then the CBP is associated with the product at block 348. Otherwise, block 348 is skipped. In either case, the configuration flow ultimately arrives at node 207, which effectively represents the end of the configuration flow.

It will be recognized that, given the flowchart of FIGURE 8, it would be straightforward to implement this flowchart in a computer, where the diamond-shaped blocks represent questions presented to a purchaser, and the rectangular blocks identify the components which are to be included in the product being configured, as a function of the answers given by the purchaser to the questions. The questions may be presented dynamically and in sequence as

the computer proceeds through the flow sequence represented by the flowchart of FIGURE 8. Alternatively, the questions may all be presented and answered in advance, and the answers then stored, before the computer begins the flow sequence represented by FIGURE 8. The computer would then carry out the flow sequence of FIGURE 8, referring to the stored answers each time it reached one of the diamond-shaped decisional blocks.

It will be evident from the foregoing discussion and from FIGURE 8 that a purchaser is presented with a short set of questions that are relatively easy to answer, because they relate to functional characteristics which the purchaser wants the resulting product to have in the purchaser's system. For example, the purchaser can readily specify the type of network element needed, the speed for transport interfaces, the reach for transport interfaces, whether protection is required for transport interfaces, whether ATM interface capability is needed, the type and quantity of tributary interfaces, the reach of tributary interfaces, and whether protection is needed for tributary interfaces.

In order to provide this information, the customer needs little or no technical knowledge regarding the internal considerations of the product itself. For example, the customer does not need to be familiar with the configuration of slots 131-159 within the shelf 101, does not need to know which slots are half-height and which are full-height, does not need to be familiar with various circuit cards that can be inserted into the slots, does not need to know which cards must go in a half-height slot and which must go in a full-height slot, and so forth.

The product configuration technique according to the present invention can also be considered from a mathematical perspective. In this regard, for a given

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B) If the two cards are the same type, then the quantity is considered to be one for the formula ($x=1$), as follows:

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A) For four of only one type (all the same):

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$$3 * {}^4C_2 = 4! (2! * (4-2)!) = 3 * 6 = 18$$

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D) For four of four types (all different):

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The given component just discussed, which has four types ($n = 4$), and which can be used in a quantity of 1, 2 or

4 (x = 1, 2 or 4), corresponds directly to the only component of the disclosed embodiment which is in Class 2, namely the IFA6 component (with respect to its use for transport interfaces). FIGURE 9 is a chart providing information regarding the components of the disclosed embodiment which correspond to Class 2, and FIGURE 9 thus lists only a single component. As evident from the foregoing discussion, the total number of mathematical combinations which are possible for this component is 49, and this is shown in the second column of the chart in FIGURE 9. The remaining columns in FIGURE 9 show how engineering considerations or "rules", in combination with the criteria set associated with Class 2, are sufficient to define a mapping between each valid product and a valid combination of Class 2 components. In this regard, a limitation imposed by engineering considerations is that, although there are four types of the IFA6 component which can be used for transport interfaces, these types are not mixed within any given product. In other words, only one type is used in any given product, in a quantity of either one, two or four. Thus, for each of the four types, there are three possible configurations in terms of quantity (one, two or four), or in other words a total of twelve valid combinations of Class 2 components. Thus, even though the total number of possible combinations has been determined mathematically to be 49, engineering rules reduce the number of valid combinations from 49 to 12, and 12 therefore appears in the column of FIGURE 9 entitled "Engineering Rules".

The criteria set for the Class 2 components can then be used to determine which of these twelve valid combinations of Class 2 components should be used in any particular product. The remaining columns in FIGURE 9 represent the various criteria (discussed above) which are

in the criteria set for Class 2 components. Working from left to right through the columns in FIGURE 9 which represent the criteria set, the first column corresponds to the criteria identifying the type of network element. This criteria has the effect of reducing the number of valid combinations to either eight or four, depending on the particular type of network element specified, as indicated in the column in FIGURE 9.

The next column corresponds to the criteria of transport interface rate or speed. Specifying the speed or rate for the transport interfaces has the effect of limiting the number of valid combinations to four, as indicated in FIGURE 9. Then, with reference to the next column, specifying whether protection is to be provided for transport interfaces effects a reduction in the number of valid combinations from four to two. Next, specifying the reach for transport interfaces reduces the possible choices to one of the twelve valid combinations, as indicated in the right column of FIGURE 9.

Summarizing, the engineering rules specify that, of the total possible mathematical combinations of 49, only 12 are valid combinations for use in products, and the criteria set for Class 2 components is adequate to guarantee that the proper one of these twelve valid combinations will be accurately chosen for purposes of configuring any specific product.

FIGURE 10 shows a similar analysis for the components in Class 3. FIGURE 10 is generally similar to FIGURE 9, and therefore not discussed separately in detail.

Engineering rules of the type discussed above reduce the number of possible combinations by effectively combining components into subcombinations, referred to as component sets. In this regard, and as a different example, a product which required a multiplexer component

might also always require a demultiplexer component. If so, then the multiplexer and demultiplexer components would together form a component set. The criteria sets discussed above, which may also be referred to as business rules, create configurations from the component sets and the components, in order to form products.

In the disclosed embodiment, and as evident from the foregoing discussion of the flowchart of FIGURE 8, the criteria set for Class 2 components is applied first, followed by the criteria set for Class 3 components, and then the criteria set for ancillary components. However, two or more of these criteria sets for respective classes can be collectively viewed as a combined criteria set, and the components from each of the corresponding classes can be collectively viewed as a component group.

The multiplexer apparatus 10 of FIGURE 1 is from the field of telecommunications, and in the context of this exemplary apparatus and field, the questions corresponding to all criteria sets are presented in an order which generally reflects the following hierarchy:

- 1) Questions that have network architecture or topology implications (such as the network element type).
- 2) Questions that have network or global implications (such as the transport speed).
- 3) Questions that have nodal or local implications.
- 4) Questions that have span implications (such as the reach).
- 5) Questions that have drop capacity implications (such as the number and type of tributaries).
- 6) Questions that have ancillary equipment implications (such as whether to provide a circuit breaker panel).

However, it will be recognized that the items in this

hierarchy are specific to an apparatus in the telecommunications field, such as that shown at 10 in FIGURE 1. For other types of products and/or other fields, the nature and sequence of questions may be different from those which apply to a telecommunications product of the type shown at 10 in FIGURE 1.

The present invention provides a number of technical advantages. One such technical advantage is that the invention facilitates generation of a configuration procedure which is purchaser friendly, because it presents a limited number of questions which are easy for a customer to answer, and does not require that the purchaser have any significant technical familiarity with internal engineering considerations and limitations. A further advantage is that the configuration procedure generated according to the invention provides accurate and reliable configuration of products based on the information provided by the customer. Further, the invention ensures that the resulting configuration procedure is capable of reliably and accurately handling every possible configuration of components that represents a valid product. Still another advantage is that, for any given apparatus, the invention facilitates development of a configuration procedure using a methodical approach which significantly reduces the time and effort needed to develop the configuration procedure.

Although one embodiment of the invention has been disclosed in detail, it will be should understood that various alternations can be made without departing from the scope of the invention. Further, although the foregoing discussion explains how the present invention can be applied in the specific context of a telecommunications apparatus, it will be recognized that the subject matter of the present invention is applicable to a variety of other types of devices.